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AGRONOMIC EVALUATIONS OF AN ARKANSAS ROCK PHOSPHATE[1]

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Raw rock phosphate is the name of fertilizer made from finely ground calcium phosphate rock; its general formula is $Ca_{10}(PO_4)_6(F,Cl,OH)_2$.

During earlier decades such material was rather widely used as a phosphorus fertilizer. But in modern agriculture only an insignificant percentage of the total phosphorus fertilizer is applied in this form. Most of the commercial phosphorus fertilizer now marketed is manufactured by treating the ground rock phosphate with sulfuric acid, or otherwise processing it, so that the orthophosphate ion exists as the more soluble $H_2PO_4^-$ or HPO_4^{-2} rather than as the insoluble PO_4^{-3} form which is found in native rock phosphate.

It has been known for three quarters of a century that several north Arkansas counties contained calcium phosphate deposits. At least one of these deposits was being mined at the turn of the century (1). But phosphate rock mining had been discontinued for many years prior to 1962 when a deposit located near Peyton Creek just off U. S. Highway 65 on the Searcy-Van Buren County border was opened for commercial exploitation.

The four greenhouse phosphorus plant uptake experiments described here were undertaken in an attempt to compare this Peyton Creek ground rock phosphate with other rock phosphates and with monocalcium phosphate. Numerous comparisons between ground rock and processed phosphorus fertilizers have been made, with widely varying soils and plant species, during the last century.

Rogers et al. (5) in 1953 gave an extensive review of the literature comparing the agronomic value of ground rock phosphate and superphosphate fertilizer. Hinkle (3), summarized the results of a 40 year crop rotation experiment on a Zanesville-Waynesboro silt loam in northwest Arkansas where rock phosphate was applied at 1.6 to 2.0 times the P_2O_5 rate of superphosphate. He reported that superphosphate was superior to rock phosphate the first two to three rotation cycles (8-12 years) for both corn and oats on soils not otherwise limed or fertilized; however rock phosphate was equal to or better than superphosphate on these crops during the remaining cycles. On plots that had been limed, and fertilized with nitrogen and potassium, superphosphate was superior to rock phosphate during the first four rotation cycles for corn, eight cycles for oats and throughout the entire 40 years for wheat and red clover. There have been two recent publications

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reporting field studies: Moschler and Jones (4) summarized the results from a number of Virginia experiments and found that one pound of P_2O_5 from superphosphate was equivalent to 1.9 pounds of P_2O_5 from rock phosphate for corn, 4.2 pounds for wheat, 2.0 for red clover and 1.7 for alfalfa. They concluded that annual applications of superphosphate supplemented with rock phosphate at 6-year intervals generally produced higher yields than either source along. Ensminger and Pearson (2) conducted a series of experiments in several southeastern states and concluded that, (a) the effectiveness of rock phosphate varied widely among the soils of the region but was seldom more than one-fourth that of superphosphate applied at the same rate of P, (b) the residual effect of rock phosphate was less or no better than that of superphosphate applied at one-half the rate of P, (c) extrapolation of yield curves indicated that maximum yield could not be reached at any rate of P with rock phosphate as the source.

MATERIALS AND METHODS

During 1963 to 1965 several greenhouse tests were conducted comparing Peyton Creek ground rock phosphate with other ground rock phosphates, with ordinary superphosphate fertilizer and a monocalcium phosphate reagent. The fertilizers used were:

a. Peyton Creek Rock Phosphate obtained from the mine near Leslie, Arkansas. This material contained 9.42% P.

b. Tennessee Brown Rock Phosphate containing 13.30% P.

c. Florida Hard Rock Phosphate containing 14.17% P.

d. Colloidal Soft Phosphate containing 8.75% P. Colloidal Phosphate is a trade name applied to a by-product of the hydraulic mining of rock phosphate. The material is a mixture of rock phosphate and colloidal clay.

e. Monocalcium phosphate reagent containing 24.60% P.

f. Ordinary superphosphate (0-20-0) fertilizer containing 8.73% P; phosphorus in this fertilizer is in the form of monocalcium phosphate.

Test No. 1 was conducted in 1963 on topsoil taken from an acid, infertile Parsons silt loam. The phosphorus fertilizer was mixed with 3 kgm of soil before potting. Rates and forms of phosphorus used are given in table 1. Successive crops of soybeans, and German millet **(Setaria italica)** were grown. The test was completely randomized with 3 repetitions.

Test No. 2 was similar to the first; the phosphorus fertilizers, (Table 2) equivalent to 130 ppm P were mixed with 1.36 kgm of topsoil taken from a slightly acid, moderately fertile Waynesboro silt loam. German millet was planted and two forage harvests were made. The plant material was dried, ground and analyzed for total P. The test was completely randomized with 5 repetitions. In tests 1 and 2 nitrogen, potassium and trace element fertilizers were added as needed. Tests No. 3 and 4 employed the Stanford-DeMent (6) short term nutrient absorption technique. In test No. 3 the oats were planted in a 12 oz. bottomless cardboard squat (cottage cheese type) cup filled with a weighed quantity of pure white sand and fertilized with a -P nutrient solution. Sixteen days after planting, and when the oat roots had ramified the sand, the bottomless cup with its sand and growing oats intact was placed inside of a similar cup containing 200 grams of soil. The treatment variables included five fertilizer sources (graph 1) and five rates; 0, 10, 20, 50 and 100 mgm of P from each source were mixed with the 200 grams of soil. The oats were permitted to grow another 7 days, during which time the roots of the phosphorus deficient plants exploited the soil for' plant available' phosphorus. The plant tops were then harvested, dried, ground and analyzed for total P. Test No. 4 varied from the above procedure in that the oat seed was planted in white sand in an intact cup. Pure rock phosphate (no soil was used) was layered in the bottom of the cups. These experiments were also completely randomized with 5 repetitions.

RESULTS AND DISCUSSION

The data in table 1 indicate the rate at which the various forms of phosphorus were added to the soil and the forage yields of soybeans and millet crops. The rock phosphates were applied at rates of 500 and 1500 pounds of fertilizer per 2 million pounds of soil (weight of 1 acre to plow depth), but since the % P of these fertilizers varied the amount of P applied varied. Nevertheless, it is apparent that superphosphate, and Tennessee, Florida and colloidal rock phosphates applied at the high rates, were the only treatments that significantly increased plant yields. The last three columns give the soil test values 75 days

phosphorus		yield, gm d.m./pot		soil test values	ppm	
source	ppm added	soybeans	millet	pH	P	Ca
none	--	19.4	1.7	4.7	6.5	467
Peyton Creek	21.8	21.4	1.9	4.6	7.2	479
Peyton Creek	65.5	18.8	2.9	4.7	8.3	517
Tennessee	32.7	20.3	2.0	4.6	7.6	475
Tennessee	98.2	23.6	4.5	4.7	9.2	491
Florida	36.7	19.4	2.6	4.7	10.0	508
Florida	110.2	22.5	4.6	4.9	13.1	463
Colloidal	20.3	19.1	2.3	4.7	8.1	475
Colloidal	58.5	22.3	1.8	4.9	9.4	475
superphosphate	7.2	22.7	2.5	4.3	7.6	458
superphosphate	21.8	23.7	4.1	4.6	9.4	489
superphosphate	65.5	23.7	5.8	4.7	12.7	483
$LSD_{.05}$		2.53	1.55			

Table 1. Effect of source and quantity of phosphorus on plant growth and on residual available soil phosphorus in test No. 1.

after the phosphorus fertilizers were mixed with the soil. None of fertilizers had any appreciable effect on the soil acidity or the quantity of exchangeable calcium. The phosphorus values represent the plant available fraction that is leached from the soil by a 0.03 N NH_4F — 0.025 N HC1. extracting solution. Most of the fertilizer phosphorus added to this acid soil remained in, or was converted into, an unavailable form.

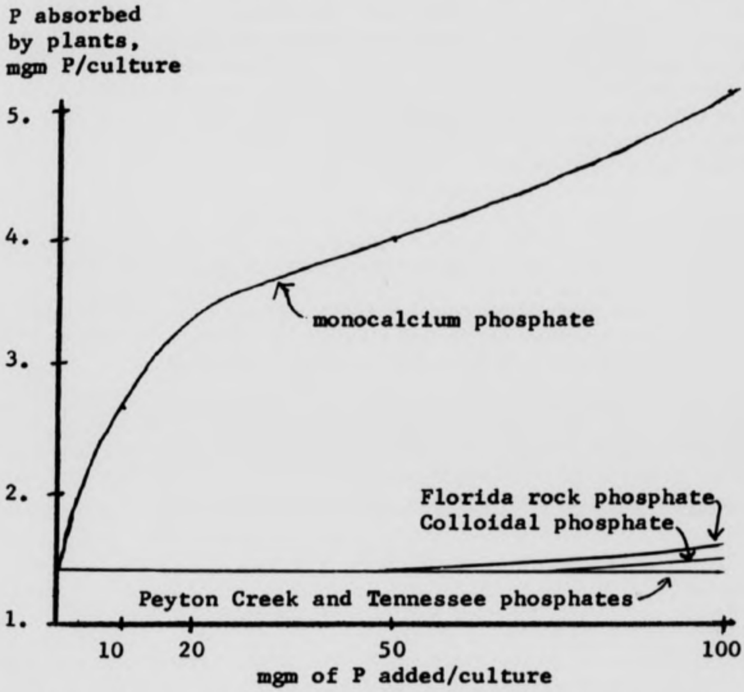
The results of test No. 2 are given in table 2. The German millet was permitted to grow until maximum growth was obtained, it was clipped 2 inches above soil level and regrowth was permitted to develop for a second harvest. The forage yields and the plant phosphorus reported in this table are the sum of both clippings. Only the monocalcium reagent significantly increased yields or was absorbed by the plants in significant quantities. The rock phosphates had only a negligable effect on the quantity of available phosphorus present in this soil at the end of the test, but the monocalcium phosphate had more than doubled the phosphorus fertility of this slightly acid soil.

source	yield gm d.m./pot	P absorbed mgm/pot	available P ppm
none	4.85	6.46	35
Peyton Creek	5.34	8.46	39
Tennessee	4.43	7.43	37
Florida	5.22	7.63	37
monocalcium phosphate	6.90	20.16	80+
$LSD_{.05}$	1.32	2.70	

Table 2. Effect of four phosphorus fertilizers added at the rate of 130 ppm P on millet yield, P absorbed by plants and residual available soil P level in test No. 2.

Test No. 3, involving 125 individual cardboard cup plantings, was the most extensive of the greenhouse tests. The results, given in graph 1, show that the rock phosphates, at whatever rates, were no improvement over the no-phosphorus check; the mono-calcium phosphate, however, was readily adsorbed by the oat plants even when low rates were applied. The dry weight clippings of each culture weighed approximately one gram. No weight differences resulted from the phosphorus treatments. The phosphorus content in the forage of the no-phosphorus and rock phosphate treatments was approximately 0.14% while the P content of the high mono-calcium treatment was approximately 0.5%.

Test No. 4 was similar to test No. 3 except that the oat plants grew in a pure sand fertilized with a -P nutrient solution. In the bottom of the growing cartons, beneath the white sand, rock phosphate fertilizer, in quantities equivalent to 1.88 gms of P, was layered. After the oat plants germinated the roots grew into these rock phosphates. The oats were harvested near the sand level 19, 35 and 50 days after planting. The plant samples from the first harvest were lost in analysis, but the samples from the second and third clippings were analyzed for phos-



Graph 1. Source and rate of fertilizer on P absorbed by young oat plants in test No. 3.

phorus. The total quantity of P in the aerial portion of the oat plants for these two clippings was 0.5, 0.5, 1.2, 0.9 and 1.7 mgms for the no-phosphorus check, Peyton creek, Tennessee, Florida, and Colloidal rock phosphates, respectively. The dry-weight yield of an oat clipping from each carton was approximately 1 gram; thus the phosphorus content of the oat forage in test 4 was abysmally low, ranging from about 0.03 to 0.1%. Under the short term growth conditions that existed in this test the oat roots were able to absorb little or none of the phosphorus from the rock phosphate even though their roots were in direct contact with it.

The results of these greenhouse tests show that these four sources of rock phosphate are approximately equally unsatisfactory sources of P under the conditions of these tests. There is no single adequate method of measuring phosphorus availability to plants. Admittedly, short-term uptake tests, such as those reported here usually show rock phosphate to be inferior to processed phosphate fertilizer as a source of plant available phosphorus. These tests do indicate that short term crops, having a high phosphorus requirement, should not be fertilized with rock phosphate. And certainly rock phosphorus is not an adequate source of fertilizer to be placed in a band near the seed row; during this critical period when the young plant needs an abundant supply of a plant available form of P, rock phosphate will have little value. These tests do not evaluate rock phosphate for those perennial or permanent plant species that do not have a high phosphorus requirement; nor do they evaluate the practice of using rock phosphate as a long term investment in soil fertility in contrast to the fertilization of the current seasons crop.

SUMMARY AND CONCLUSIONS

Four greenhouse tests comparing the fertilizer value of an Arkansas rock phosphate with 3 other more-or-less widely known rock phosphates and with a mono-calcium phosphate source are reported.

The Peyton Creek rock phosphate from near Leslie, Arkansas was no better than the other rock phosphates in increasing plant yields, in being absorbed by the plants, or in increasing the 'available' phosphorus level in the soil. The monocalcium phosphate source was markedly superior to the rock phosphates as measured by these tests.

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